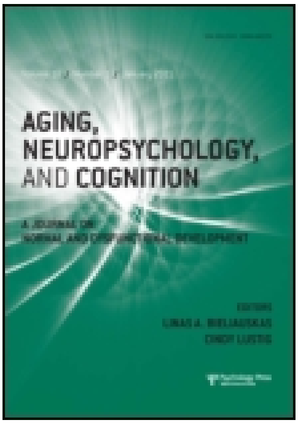

Aging, Neuropsychology, and Cognition: A Journal on Normal and Dysfunctional Development
Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/nanc20

Memory, priority encoding, and overcoming high-value proactive interference in younger and older adults

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Published online: 30 Jan 2013.

Aging, Neuropsychology, and Cognition, 2013
Vol. 20, No. 6, 660–683, http://dx.doi.org/10.1080/13825585.2012.762083

Memory, priority encoding, and overcoming high-value proactive interference in younger and older adults

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ABSTRACT

It is often necessary to remember important information while directing attention away from encoding less valuable information. To examine how aging influences the ability to control and update the encoding of high-value information, younger and older adults studied six lists of words that varied in terms of the point values associated with each word. The words were paired with the same high and low point values for three study-test cycles, but on the fourth and subsequent cycles the value-word pairings were switched such that the lowest value pairs became the highest values (and vice versa). For the first three study-test cycles, younger adults outperformed older adults in terms of the number of words recalled and overall point totals, but performance was similar in terms of selectively remembering high-value words. When the values were switched, both groups displayed substantial interference from the previous pairings. Although both groups improved with additional study-test cycles, only younger adults were able to fully recover from the interference effects. A similar, and more pronounced, set of results were obtained when positive and negative point values were paired with the words. The findings are interpreted in a value-directed remembering framework, emphasizing the role of benefits and costs of strategic encoding and age-related differences in the effects of interference on memory.

Keywords: Memory; Aging; Interference; Value-directed remembering.

We thank Niki Kittur, Teal Eich, Matt Rhodes, and Shannon McGillivray for helpful insight and contributions at various points. We also thank Bob Bjork for useful comments on previous versions of the manuscript. Portions of this research were presented at the 13th Biennial Cognitive Aging Conference in Atlanta, Georgia, April 2010.

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In order to remember important information successfully, it is necessary to pay attention to this high-value information, often at the expense of less important information. For such "value-directed remembering" to be successful—that is, the ability to direct attention towards remembering the most important information—operations such as strategic control and inhibition may be important cognitive mechanisms (Castel, 2008). Strategic control is the ability to focus attention on certain information, which can require the use of working memory and metacognitive monitoring to maintain that focus (e.g., Engle & Kane, 2004; Rhodes & Kelley, 2005). Inhibitory processes are needed to prevent irrelevant or competing information from interfering with current goals (e.g., Anderson & Spellman, 1995; Hasher, Lustig, & Zacks, 2007). These processes play a crucial role when one attempts to remember important information, as well as when interference may be present from prior learning (e.g., Jacoby, 1999). For example, when a friend gets married and takes a new last name, the former last name (which has been strengthened in memory from years of use and familiarity) must be then inhibited, while the new last name becomes more relevant and of high-value for future use. The current study examines age-related differences in the ability to monitor, remember and then update high-value information and to overcome interference from previous "high-value" information.

Older adults typically display pronounced episodic memory deficits and often show impairments in various attentional tasks that involve cognitive control. For example, older adults have reduced working memory capacity and cognitive control relative to younger adults (e.g., Verhaeghen & Basak, 2005), and there are age-related reductions in task-switching performance (see Kramer, Hahn, & Gopher, 1999). Given these deficits in memory capacity and attentional control, it is important for older adults to strategically regulate attention towards encoding and remembering the most critical information in order to successfully retrieve it later. To examine how older adults can strategically remember high-value information, previous research has utilized a "selectivity task" in which words are paired with point values and participants attempt to maximize their score by remembering high-value words (e.g., words paired with higher point values, see Castel, 2008; Castel, Balota, & McCabe, 2009; Castel, Benjamin, Craik, & Watkins, 2002; Castel, Farb, & Craik, 2007; Castel et al., 2011; McGillivray & Castel, 2011). In this type of experimental setting, younger adults typically remember more words than older adults, but often there are small or no age-related differences in terms of remembering high-value words (see Castel, McGillivray & Friedman, 2012, for a recent review). However, it is unclear how older adult accomplish this in light of deficits in cognitive control.

In the selectivity paradigm, participants are presented with a series of word lists, with each word in the list having a distinct value (e.g., ranging from 1 to 12). Participants are instructed to remember as many words as possible, with the goal of maximizing their score, which is the sum of the point values of each word they successfully recall. After recall, participants are told their score as a form of feedback, and then are given a new list of words, again with instructions to maximize their score. Using a selectivity index (SI) developed by Watkins and Bloom (1999; see also Castel et al., 2002; Hanten et al., 2007), one can examine participants' ability to be selective, as well as how selectivity changes with task experience. This SI is based on a participant's score (the sum of the points that were paired with the recalled items, or the "value" of the recalled items), relative to "ideal" performance. For example, if a given participant remembered four words, and the points associated with the words were 12, 10, 9, and 8, that participants' SI would be considered quite high. The ideal (i.e., highest) score for four words would be 42 (i.e., 12+11+10+9 = 42), whereas the score of the participant in question is 39. Thus, the SI in this case is 39/42 = 0.93, with perfect selectivity resulting in an SI of 1.0. The selectivity index can provide additional insight (i.e., beyond simple measures of memory quantity and accuracy) regarding how people strategically remember high-value information, at the expense of lower-value information.

While strategically attending to high-value items typically leads to enhanced recall of this information, one must also strategically inhibit or ignore lower-value information in order to maximize desired outcomes. Older adults often display pronounced deficits in inhibitory control mechanisms in a variety of tasks (Hasher & Zacks, 1988). In addition, older adults are not only highly susceptible to such intrusions, but are also confident those errors in memory are factual (Jacoby & Rhodes, 2006). However, the literature on whether older adults have decreased inhibitory function in different contexts is somewhat mixed. For instance, in item-method directed forgetting (i.e., a paradigm which examines inhibitory control by cuing participants to explicitly forget certain items while encoding others, yet are given surprise instructions to retrieve all items at test regardless of the initial remember/forget cue), older adults sometimes show typical directed forgetting effects that are comparable to their younger counterparts (Sego, Golding, & Gottlob, 2006; Zellner & Bauml, 2006), while in other studies they retrieve more to-be-forgotten items at test compared to younger adults—illustrating inhibitory impairments (Dulaney, Marks, & Link, 2004; Zacks, Radvansky, & Hasher, 1996). A similar discrepancy occurs with retrieval-induced forgetting paradigms in that older adults sometimes do not show the same levels of forgetting for related, yet competing, items as younger adults while in other cases they do (Aslan, Bauml, & Pastortter, 2007; Hogge, Adam, & Collette, 2008). When negative value words (i.e., words that will be detrimental to one's score) are incorporated into the selectivity task, older adults are more likely than younger adults to later recognize (but not recall) these negative value words (Castel et al., 2007), consistent with the inhibitory deficit notion.

The present study examines how younger and older adults prioritize the encoding of high-value information in situations in which high-value information has previously been encountered as low-value information. Specifically, we were interested in whether age-related differences exist in the ability to overcome proactive interference from previously high-value information. While prior work has shown that older adults can successfully encode high-value information, it is unclear if this can occur in the presence of interference from prior materials and processes. Older adults are particularly susceptible to proactive interference (Hasher, Chung, May, & Foong, 2002; Hay & Jacoby, 1999; Jacoby, Wahlheim, Rhodes, Daniels, & Rogers, 2010), and this may prevent older adults from strategically remembering high-value information in a dynamic value-directed remembering task. Thus, while older adults may show benefits through the repeated study of high-value information, they may then be especially prone to interference if this high-value information is later presented as low-value, which can often happen in dynamic, real-world environments. The current study examines age-related differences in the ability to monitor, remember and then update high-value information, and to overcome "high-value" proactive interference.

The current study employed a modified selectivity task (e.g., Castel, 2008; Castel et al., 2002). Younger and older adult participants learned a series of the same word-point value associations across multiple study-test lists with the goal of recalling words with higher associated point values. After recalling words in each list, participants received their score as feedback, and then began the next list. After the first three study-test cycles, point values were switched such that the word with the highest associated value was now the lowest (and vice versa) for the remaining three study-test lists. What is critical in the present study is how memory is influenced for the "switched" lists and the degree to which younger and older adults can recover from the interference on subsequent study-test cycles. In Experiment 1, participants studied lists of 40 words that were paired with point values ranging from 1 to 40 in order to examine value-based proactive interference effects and how value impacts strategic encoding with task experience. In Experiment 2, participants studied a list of 40 words paired with both positive and negative point values ranging from –20 to +20. We sought to examine proactive interference and how value impacts both encoding and retrieval processes, given that recalling words associated with negative values would hurt participants' scores. We predicted that both younger and older adults would show benefits in recall and selectivity with task experience in the initial repeated study-cycles, but on the switched list, both groups would show substantial costs. We were specifically interested in whether younger, and perhaps to a lesser extent older adults, would recover from these value-based interference effects with successive study-test cycles.

EXPERIMENT 1

In Experiment 1, we examined the ability to control and update encoding of high-value information using a modified selectivity task. Younger and older adults studied six lists of words that varied in terms of the point values associated with each word. The participants' goal was to maximize their score, which was the sum of the points of the recalled words. The words were paired with the same high and low point values for three study-test cycles, but on the fourth and subsequent cycles the value-word pairings were switched such that the lowest value pairs became the highest values (and vice versa). We were especially interested in performance after the switch list (List 4), as we should expect both age groups to show an immediate drop in performance, with eventual recovery occurring on subsequent lists. If older adults are particularly susceptible to proactive interference and display deficits in inhibition (e.g., Hasher, 2007; Hasher & Zacks, 1988; Jacoby et al., 2010; Kane, Hasher, Stoltzfus, Zacks, & Connelly, 1994), then older adults should show pronounced "value-based" interference effects (i.e., older adults will be prone to recall low-value items that were formerly high value). However, with additional study test cycles, older adults may be able to recover as they implement strategic encoding of the new high-value information on later lists. To examine this recovery process, we also included control groups that did not receive the switch list (i.e., this group received six study-test cycles with the same value-word pairs). This control group allowed for an important "within age-group" comparison. While older adults may not recover to the same degree as younger adults, we were also interested in whether younger and older adults could show recovery that reached a level that was comparable to an age-matched group that did not receive the switched values on List 4 (and thus should not display value-based proactive interference). If either age group shows comparable performance to their respective control group, then this would suggest highly flexible value-based memory processes can override proactive interference.

Method

Participants

The participants were 48 undergraduate students (35 females, mean age = 20.9) from the University of California, Los Angeles and 48 healthy older adults (28 females, mean age = 78.1) from the surrounding Los Angeles area. Older adults were living independently in the Los Angeles area, and recruited through community flyer postings as well as through the UCLA Cognition and Aging Laboratory Participant Pool. The older adults had good self-reported health ratings (M = 8.3 on a scale of 1–10 with 1 indicating extremely poor health and 10 indicating excellent health), and had an average of 16.4 years of education. Older participants were paid $10 an hour for participation. Younger adults were all University of California, Los Angeles undergraduates and received course credit for participation, and had an average of 15.8 years of education.

Design

The experiment had a $2 \times 2 \times 6$ mixed design, with age group (younger adult or older adult) as a between-subjects factor, experimental condition (control or switched) as a between-subjects factor, and list (list 1, 2, 3, 4, 5, or 6) as the within-subjects factor. Participants were randomly assigned to the two different conditions of the experiment.

Materials

The stimuli were 40 words that varied from four to seven letters long. The words were common English nouns used in everyday speech (mean logarithmic frequency = 10.02, see Balota et al., 2007). The words were randomly paired with numerical values from one to 40, and then organized into a single list, which had its order randomized six times—one for each of the six lists shown to participants. Importantly, participants always studied the same 40 words in each list, and the only things that varied were the order of those words and which value they were paired with across lists. In the switched-list version of the experiment, the values paired with the words on the fourth, fifth, and sixth lists were switched such that a word that had previously paired with a point value of 40 on the first three lists (e.g., hammer 40) now was paired with point value of one (e.g., hammer 1).

Procedure

Participants were given instructions explaining the procedure prior to the first list. Each list had two phases, a study phase and a retrieval phase. During the study phase, participants viewed each of the 40 word-point value pairs one at a time for 1 second each and were instructed to remember as many of the words as they could. This study phase ended when the word "RECALL" appeared on the screen, beginning the retrieval phase for that list. During the retrieval phase, participants were instructed to verbally recall as many of the words from study phase as they could remember in 45 seconds (they did not need to recall the point value associated with the words). The experimenter wrote down the participant's verbal responses. Participants were also given instructions to maximize their point scores, which were totaled based on the associated point values paired with the words they recalled. After the 45 seconds of free recall, the experimenter calculated the point total of the words recalled, told the participant that total, and began the study phase for the next list. This process was repeated with the same word-point values pairs across all six lists for the control condition. However, for the switched condition, the point values for the fourth, fifth, and sixth lists were switched during the study phase of the experiment such that the highest point value word on the first three lists became the lowest point value word on the remaining lists, the second highest point value word became the second lowest word, etc. Importantly, the lowest point value word on the first three lists then became the highest point value word on the remaining lists. Participants in the switched condition of the study were not informed of this point value switch during the instructions. At the end of the sixth study-test list, participants were asked if they noticed any pattern across all of the lists for the word-value pairs, and if so, what that pattern was. The experimenter recorded the participants' responses.

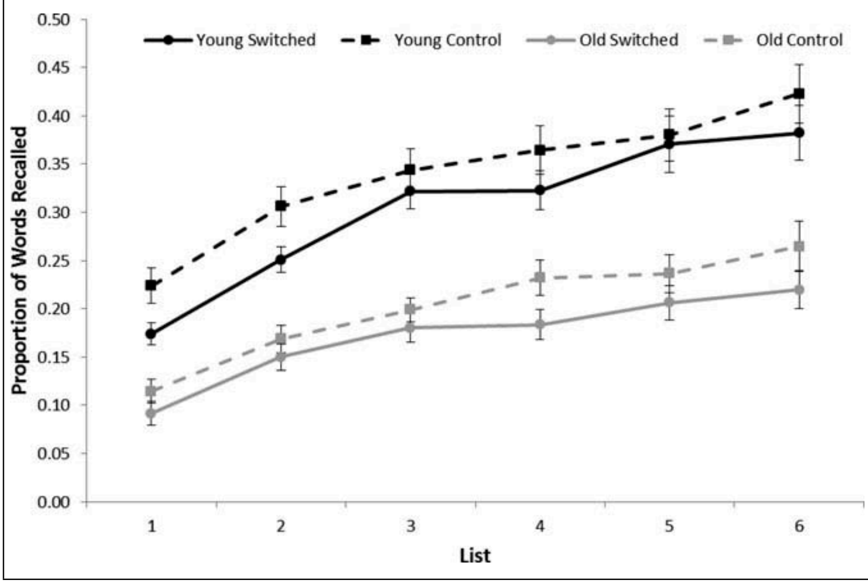
Results and Discussion

The present study yielded several converging dependent variables that were of interest, and are presented in the following order: (A) the proportion of words recalled by younger and older adults as a function of list, (B) the point totals, or score, achieved by younger and older adults as a function of list, (C) selectivity (SI) for younger and older adults as a function of list, and (D) the probability of recall as a function of value, and how this changed across lists. In addition, all of these results were examined in terms of the switch list group (the experimental group) and the group that did not receive the switch list (the control group). Of the 48 combined younger and older adult participants that received the switch list, 45 said something to the effect that they noticed the point values changed at some point during the study, indicating some awareness of a switch in values across lists.

Proportion of Words Recalled Across Lists

The proportion of words recalled across each list is presented in Figure 1. These data were analyzed using a 2 (Age Group: younger adults, older adults) × 2 (Condition: switched, control) × 6 (List: 1, 2, 3, 4, 5, 6) mixed analysis of variance (ANOVA). A main effect of age group was found such that older adults ($M = 0.19$, $SD = 0.08$) recalled fewer words than younger adults ($M = 0.32$, $SD = 0.08$), $F(1, 92) = 66.53$, $MSE = 0.039$, $p < .001$, $\eta_p^2 = .42$. A main effect of condition was found such that participants in the experimental group recalled fewer words ($M = 0.24$, $SD = 0.08$) than those in the control group ($M = 0.27$, $SD = 0.08$), $F(1, 92) = 4.13$, $MSE = 0.039$, $p < .05$, $\eta_p^2 = .04$. A main effect of list was found, $F(5, 460) = 111.05$, $MSE = 0.\ 003$, $p < .001$, $\eta_p^2 = .55$, such that each subsequent list had a significantly higher proportion of words recalled than the prior list (all ts $< .01$). A significant age group by list interaction was found, $F(5, 460) = 4.183$, $MSE = 0.003$, $p < .01$, $\eta_p^2 = .04$, such that the difference in the proportion of words recalled between lists six and one was significantly larger for younger adults than for older adults $t(94) = 2.82$,

FIGURE 1. Average proportion of words recalled in each list for younger and older adults in Experiment 1. Error bars represent the standard error of the mean.

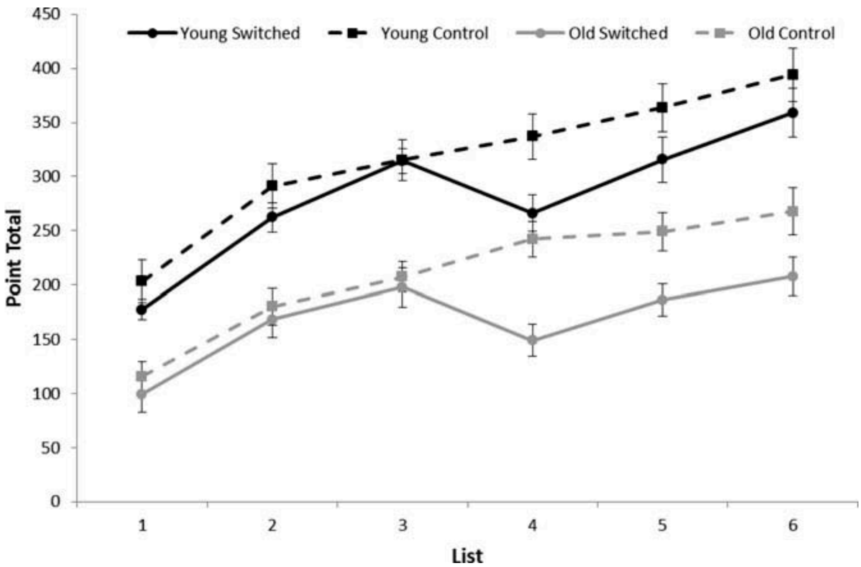


$p < .01$. All other interactions were non-significant (*F*s < 1). Importantly, both younger and older adults were able to recover from the switch in terms of words recalled. Specifically, younger adults' performance on list three ($M = 0.32$, $SD = 0.09$) was significantly lower than that on list six ($M = 0.38$, $SD = 0.14$), $t(23) = 2.65$, $p < .05$. Likewise, older adults showed a similar result (list three: $M = 0.18$, $SD = 0.07$; list six: $M = 0.22$, $SD = 0.10$), $t(23) = 3.12$, $p < .01$. It should be noted that the average recall of words was slightly higher for the control groups than for the switched groups on lists one and two (*p*s = .03 and .07, respectively), this difference was not present in list three ($p = .37$) illustrating that performance was equal across groups immediately before the switch occurred on list four.

Point Totals (Score) Across Lists

The average number of points obtained on each list by younger and older adults is presented in Figure 2. These results were analyzed with a 2 (Age Group: younger adults, older adults) × 2 (Condition: switch, control) × 6 (List: 1, 2, 3, 4, 5, 6) mixed ANOVA. A main effect of age was found revealing younger adults had higher point totals than older adults ($M = 299.9$, $SD = 71.0$; $M = 189.3$, $SD = 71.0$, respectively), $F(1, 92) = 58.39$, $MSE = 30205.97$, $p < .001$, $\eta_p^2 = .39$. A main effect of condition was found, $F(1, 92) = 7.10$, $MSE = 30205.97$, $p < .01$, $\eta_p^2 = .07$, such that participants

FIGURE 2. Average point scores for each list for younger and older adults in Experiment 1. Error bars represent the standard error of the mean.

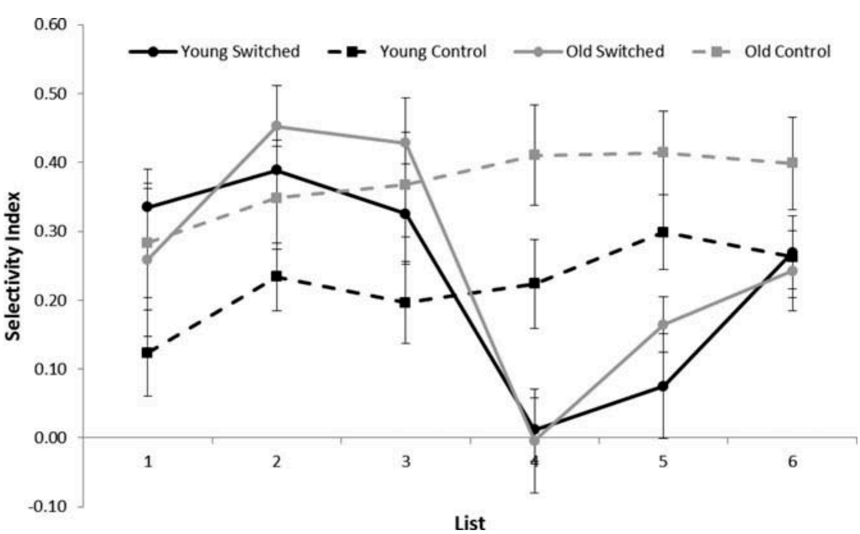


in the control condition accrued more points than the switch participants ($M = 263.9$, $SD = 71.0$; $M = 225.3$, $SD = 71.0$, respectively). A main effect of list was found, $F(5, 460) = 102.04$, $MSE = 2783.25$, $p < .001$, $\eta_p^2 = .53$, such that point totals were progressively higher across subsequent lists, with the exception that the fourth list ($M = 248.56$, $SD = 76.8$) had approximately equal performance with the third list ($M = 258.72$, $SD = 83.5$), $t(95) = 1.34$, $p = .18$. An interaction was found between age group and list, $F(5, 460) = 3.11$, $MSE = 2783.25$, $p < .01$, $\eta_p^2 = .03$, such that younger adults' score on list six was significantly higher than list three $t(47) = 4.90$, $p < .001$, while there was a significantly smaller difference between those lists' scores for older adults $t(47) = 3.34$, $p < .01$. A list by condition interaction was found, $F(5, 460) = 6.89$, $MSE = 2783.25$, $p < .001$, $\eta_p^2 = .07$, such that list three scores in the control condition ($M = 261.31$, $SD = 96.2$) were significantly lower than those on list four ($M = 289.48$, $SD = 101.1$), $t(47) = 3.01$, $p < .01$. In contrast, scores in the switch condition were higher on list three ($M = 256.1$, $SD = 93.5$) than list four ($M = 207.6$, $SD = 96.2$), $t(47) = 5.38$, $p < .001$. All other interactions were non-significant (Fs < 1). Importantly, younger adults were able to recover from the switch and surpass their performance from before the switch, while older adults were only able to recover to the level of their own performance on list three in regards to point totals. Specifically, younger adults' performance on list three ($M = 314.5$, *SD* = 54.7) was significantly lower than list six performance (*M* = 358.9, *SD* = 108.0), $t(23) = 2.38$, $p < .05$, but there was no difference for older adults for this comparison.

Selectivity Index across Lists

In order to assess the *quality* of the information recalled, selectivity indexes were analyzed. The average selectivity index score across each list is presented in Figure 3. The data from four older adults were not included in this analysis as they did not recall any words on the first list, and therefore could not have a selectivity index score calculated for their performance on that list. A 2 (Age Group: younger adults, older adults) × 2 (Condition: switched, control) × 6 (List: 1, 2, 3, 4, 5, 6) mixed ANOVA found a main effect of age, $F(1, 88) = 3.82$, $MSE = 0.282$, $p = .05$, $\eta_p^2 = .04$, such that older adults had higher selectivity index scores (*M* = 0.32, *SD* = 0.23) than younger adults (*M* = 0.23, *SD* = 0.21). A main effect of list was found, $F(5, 440) = 8.03$, $MSE = 0.058$, $p < .001$, $\eta_p^2 = .08$, such that selectivity improved across each subsequent list from the prior, except after list four, which had a decrease in performance from list three, $t(95) = 4.15$, $p < .001$. A list by condition interaction was found, $F(5, 440) = 13.31$, $MSE = 0.058$, $p < .001$, $\eta_p^2 = .13$, such that selectivity consistently improved for control participants across every list, while selectivity for switched participants significantly decreased between lists three and four $t(47) = 6.24$, $p < .001$, but continued to improve for subsequent lists. The main effect of condition,

FIGURE 3. Average selectivity index in each list for younger and older adults in Experiment 1. Error bars represent the standard error of the mean.



as well as the other interactions, were non-significant (*F*s < 1). Importantly, younger adults were able to recover their selectivity after switch while older adults could not. Specifically, selectivity was significantly lower on list six ($M = 0.24$, $SD = 0.28$) than list three ($M = 0.43$, $SD = 0.31$) for older adults, $t(23) = 2.87$, $p < .01$, but there was no significant difference for younger adults.

Probability of Recall as Function of Value

To examine whether participants were encoding and recalling high value words across each list, the proportion of words recalled from each quartile of values (i.e., 1–10, 11–20, 21–30, 31–40) from list three (immediately before the switch), list four (immediately after the switch), and list six (the last test—three lists after the switch) were calculated (see Table 1). Three separate 2 (Age Group: younger adults, older adults) × 2 (Condition: switched, control) × 4 (Quartile: first, second, third, fourth) mixed ANOVAs were conducted for the three lists examined. There was a main effect of age group on list three such that older adults ($M = 0.19$, $SD = 0.12$) recalled a smaller proportion of words overall compared to younger adults ($M = 0.33$, $SD = 0.12$), $F(1, 92) = 69.28$, $MSE = 0.028$, $p < .001$, $\eta_p^2 = .43$. A main effect of quartile was also found, $F(3, 276) = 53.13$, $MSE = 0.026$, $p < .001$, $\eta_p^2 = .37$, such that high value information (words paired with values 31–40) was recalled significantly more often compared to any other information (words paired with values 1–30).

A similar analysis was completed for lists four and six. List four had a similar pattern of results for the effect of age, $F(1, 92) = 48.36$, $MSE = 0.037$, $p < .001$, $\eta_p^2 = .35$, as well as for the effect of quartile, $F(3, 276) = 10.55$, $MSE = 0.026$, $p < .001$, $\eta_p^2 = .10$. Additionally, a main effect of condition was found such that a greater proportion of words were recalled, overall, in the control condition ($M = 0.30$, $SD = 0.14$) than the switched condition ($M = 0.25$, $SD = 0.14$), $F(1, 92) = 5.37$, $MSE = 0.037$, $p < .05$, $\eta_p^2 = .06$. The quartile by condition interaction was also found to be significant, $F(3, 276) = 11.92$, $MSE = 0.026$, $p < .001$, $\eta_p^2 = .12$, such that there was no difference in the proportion of words recalled from any given quartile for the switched participants ($F < 1$), but not for the control participants, $F(3, 138) = 19.54$, $MSE = 0.029$, $p < .001$, $\eta_p^2 = .30$, whose performance for each subsequent quartile was greater than the last (all *p* values $< .05$).

In list six, there was the same effect of age group, $F(1, 92) = 38.42$, $MSE = 0.064$, $p < .001$, $\eta_p^2 = .30$—older adults recalled a smaller proportion of words across the value quartiles ($M = 0.24$, $SD = 0.12$) compared to younger adults ($M = 0.40$, $SD = 0.12$). An effect of quartile similar to that of lists three and four was found, $F(3, 276) = 42.93$, $MSE = 0.026$, $p < .001$, $\eta_p^2 = .32$. Lastly, a condition by quartile interaction was found, $F(3, 276) = 5.39$, $MSE = 0.026$, $p = .001$, $\eta_p^2 = .06$, such that participants

TABLE 1. Mean proportion of words recalled across point value quartiles as a function of age group and experimental condition for lists three, four, and six

		Quartile			
Experiment	Group	1st	2nd	3rd	4th
List 3					
	Values:	(1 to 10)	(11 to 20)	(21 to 30)	(31 to 40)
Experiment 1	Younger Adults (Switched)	0.18	0.24	0.33	0.54
	Younger Adults (Control)	0.25	0.29	0.39	0.45
	Older Adults (Switched)	0.05	0.10	0.23	0.34
	Older Adults (Control)	0.09	0.17	0.18	0.36
	Values:	(−20 to −11)	(−10 to −1)	(1 to 10)	(11 to 20)
Experiment 2	Younger Adults (Switched)	0.01	0.01	0.46	0.63
	Younger Adults (Control)	0.00	0.01	0.48	0.67
	Older Adults (Switched)	0.01	0.02	0.24	0.48
	Older Adults (Control)	0.04	0.03	0.23	0.42
List 4					
	Values:	(1 to 10)	(11 to 20)	(21 to 30)	(31 to 40)
Experiment 1	Younger Adults (Switched)	0.32	0.34	0.33	0.30
	Younger Adults (Control)	0.26	0.34	0.39	0.47
	Older Adults (Switched)	0.18	0.22	0.14	0.20
	Older Adults (Control)	0.13	0.16	0.22	0.43
	Values:	(−20 to −11)	(−10 to −1)	(1 to 10)	(11 to 20)
Experiment 2	Younger Adults (Switched)	0.02	0.02	0.22	0.42
	Younger Adults (Control)	0.00	0.00	0.56	0.71
	Older Adults (Switched)	0.06	0.07	0.12	0.33
	Older Adults (Control)	0.01	0.03	0.18	0.53
List 6					
	Values:	(1 to 10)	(11 to 20)	(21 to 30)	(31 to 40)
Experiment 1	Younger Adults (Switched)	0.27	0.30	0.48	0.48
	Younger Adults (Control)	0.26	0.34	0.47	0.56
	Older Adults (Switched)	0.13	0.21	0.27	0.26
	Older Adults (Control)	0.15	0.20	0.24	0.47
	Values:	(−20 to −11)	(−10 to −1)	(1 to 10)	(11 to 20)
Experiment 2	Younger Adults (Switched)	0.01	0.02	0.37	0.58
	Younger Adults (Control)	0.02	0.00	0.58	0.79
	Older Adults (Switched)	0.03	0.02	0.22	0.41
	Older Adults (Control)	0.02	0.02	0.34	0.58

in the switched condition recalled an approximately equal amount from the third and fourth quartiles, while participants in the control condition recalled significantly more from the fourth quartile than the third $t(47) = 5.38$, $p < .001$.

In summary, the results show that both younger and older adults can exhibit efficient value-directed remembering with successive study-test lists (in terms of SI prior to the switch list). Namely, both age groups could selectively recall high-value information (see Figure 3 and Table 1). However, when the value of to-be-remembered information changed, both groups showed value-based interference effects. While both age groups improved their performance after the switch list, only the younger adults were able to fully recover and improve their performance in terms of value-directed remembering (i.e., point totals and selectivity).

EXPERIMENT 2

In Experiment 1, both younger and older adults experienced interference from previously studied high-value information, but both groups were able to overcome this interference (to varying degrees) with successive study-test cycles. However, only the younger adults recovered to the same levels of performance relative to the control group that did not receive the switch in values. We conducted a second experiment to provide a conceptual replication of Experiment 1, and a stronger test of inhibitory control and source monitoring when participants encounter words that are paired with negative and positive values, with recall of negative point value words being associated with a penalty, or decrement, in terms of overall score. In Experiment 2 words were paired with both negative and positive point values such that, on the switch list, the positive-value words became negative-value words. Consequently, recalling these words would result in a reduction in score. We expected a similar pattern of results to Experiment 1—with both age groups performing well on the first set of lists. However, after the switch occurred, we expected both younger and older adults to show decrements in selectivity as a result of being unable to effectively inhibit previous responses in favor of once inhibited responses. Unlike Experiment 1 where recall of any word could enhance score, recall of a previous high value word would result in a reduction in score (as those words are now negative in value). Thus, source monitoring may play a role, as participants will have to monitor retrieval such that formerly high-value information is not recalled. Given that older adults often show deficits in source memory and source monitoring (Johnson, Hashtroudi & Lindsay, 1993), we expect them to have a more dramatic drop in selectivity scores after the switch list, relative to younger adults.

Participants

The participants were 42 University of California, Los Angeles undergraduate students (29 females, mean age = 20.12) and 36 healthy older adults (28 females, mean age = 72.81) from the surrounding Los Angeles area. The older adults had good self-reported health ratings ($M = 9.0$), and had an average of 16.1 years of education. The younger adult participants had an average of 15.9 years of education. All participants were recruited and compensated in the same manner as described in Experiment 1.

Design and Materials

The design and materials were nearly identical to Experiment 1.

Procedure

The procedure was fairly similar to Experiment 1, with the exception that the point values now ranged from –20 to +20 (with no word assigned a point value of zero). This point value manipulation impacted scores such that if negatively valued words were accidentally recalled by participants during the retrieval phase, their associated values would be subtracted from the participant's point total. Thus, it was very important for participants to recall only the positive words, as well as the words with the highest positive values possible. This information was conveyed in the initial instructions such that participants were aware of the detrimental impact of negative words on their point totals.

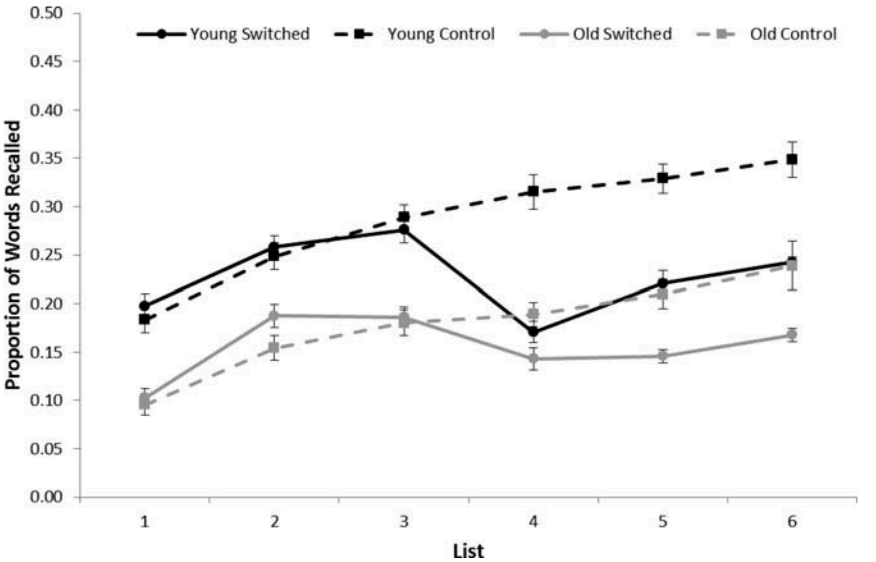
Results and Discussion

Proportion of Words Recalled Across Lists

The proportion of words recalled across each list is presented in Figure 4. A 2 (Age: young, old) × 2 (Condition: switched, control) × 6 (List: 1, 2, 3, 4, 5, 6) mixed ANOVA showed all three main effects and several interactions for words recalled. A main effect of age was found, $F(1, 74) = 77.25$, $MSE = 0.012$, $p < .001$, $\eta_p^2 = .51$, such that older adults recalled fewer words overall ($M = 0.17$, $SD = 0.04$) than younger adults ($M = 0.26$, $SD = 0.05$).

A main effect of condition was found, $F(1, 74) = 15.41$, $MSE = 0.012$, $p < .001$, $\eta_p^2 = .17$, such that participants in the switched condition recalled a smaller proportion of words ($M = 0.19$, $SD = 0.05$) relative to controls ($M = 0.23$, $SE = 0.04$). A main effect of list was found, $F(5, 370) = 61.74$, $MSE = 0.002$, $p < .001$, $\eta_p^2 = .46$, such that each subsequent list had a significantly higher proportion of words recalled than the prior list with the exception of list four, $t(77) = 3.90$, $p < .001$. A significant condition by list interaction was also found, $F(5, 370) = 35.50$, $MSE = 0.002$, $p < .001$, $\eta_p^2 = .32$, such that the proportion of words recalled at list four was approximately equal to that of list one for switched participants, but was significantly greater for controls, $t(35) = 12.01$, $p < .001$. Lastly, an age by condition by list interaction was found, $F(5, 370) = 3.72$, $MSE = 0.002$, $p < .01$, $\eta_p^2 = .05$, such that the difference between list three and list four performance for younger adults was larger in magnitude than it was for older adults. Specifically, younger adults' recall in the switched condition decreased, $t(23) = 7.63$, $p < .001$ while

FIGURE 4. Average proportion of words recalled across each list for younger and older adults in Experiment 2. Error bars represent the standard error of the mean.

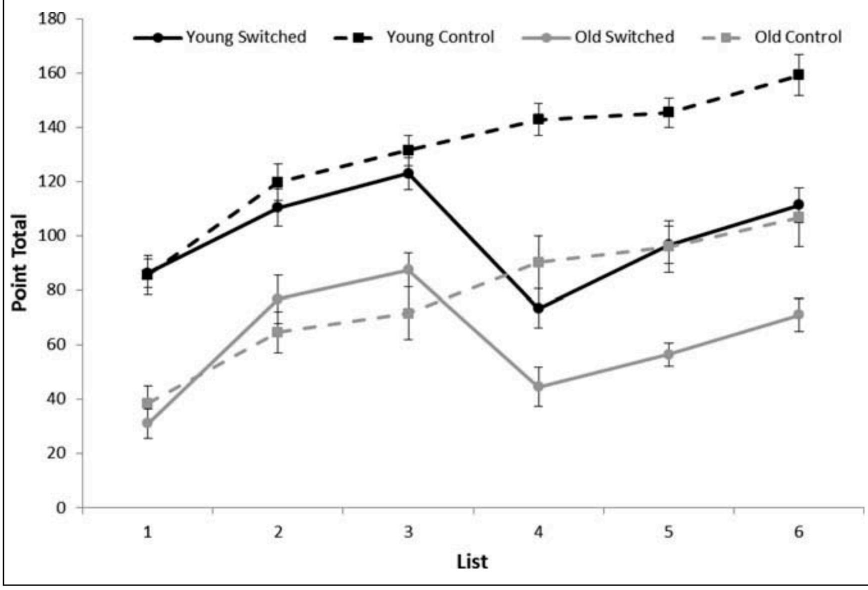


younger adults' recall in the control condition improved, $t(17) = 2.45$, $p < .05$. In contrast, older adults' recall in the switch condition decreased between lists three and four, $t(17) = 2.96$, $p = .01$, while older adults in the control condition did not show any changes. Importantly, both younger and older adults were unable to recover from the switch by the last list. Specifically, younger adults' recall was significantly higher on list three ($M = 0.28$, $SD = 0.06$) than on list six ($M = 0.24$, $SD = 0.07$), $t(23) = 3.31$, $p < .01$, while older adults showed a similar trend (list three: $M = 0.19$, $SD = 0.04$; list six: $M = 0.17$, $SD = 0.03$), $t(17) = 1.83$, $p = .085$.

Point Totals (Score) across Lists

Point totals for each list are presented in Figure 5. The maximum score a participant could get on a single list was 210 points. A 2 (Age: young, old) × 2 (Condition: switch, control) × 6 (List: 1, 2, 3, 4, 5, 6) mixed ANOVA found all three main effects and one interaction. A main effect of age was found, $F(1, 74) = 78.48$, $MSE = 3089.48$, $p < .001$, $\eta_p^2 = .52$, such that, across lists, younger adults were awarded more points ($M = 115.5$, $SD = 22.9$) than older adults ($M = 69.6$, $SD = 22.7$). A main effect of condition was found such that participants in the switch condition had significantly poorer performance relative to controls ($M = 80.7$, $SD = 22.9$; $M = 104.4$,

FIGURE 5. Average point scores from each list for younger and older adults in Experiment 2. Error bars represent the standard error of the mean.

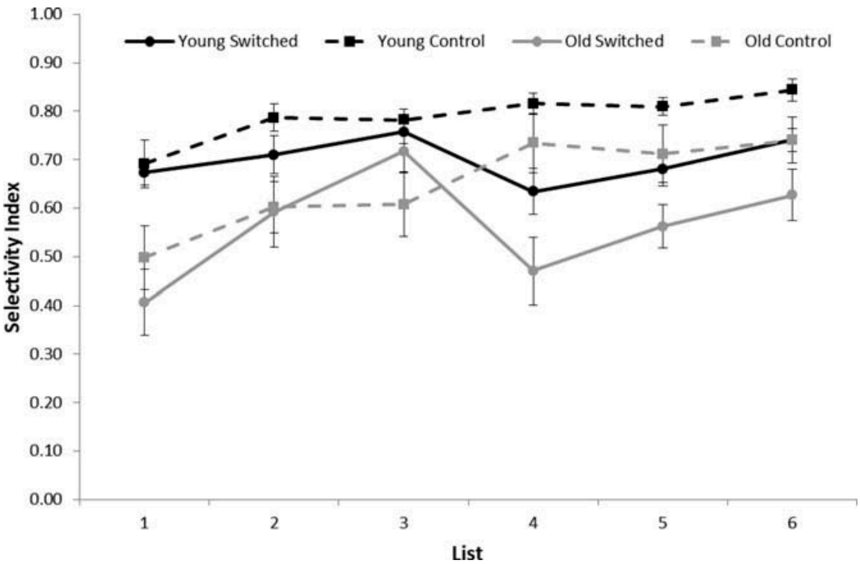


SD = 22.7, respectively), $F(1, 74) = 20.89$, $MSE = 3089.48$, $p < .001$, $\eta_p^2 = .22$. A main effect of list was found, $F(5, 370) = 47.73$, $MSE = 512.19$, $p < .001$, $\eta_p^2 = .39$, such that point totals became progressively higher across each list, with the exception of list four, $t(77) = 3.79$, $p < .001$. The interaction between condition and list was also significant, $F(5, 370) = 27.66$, $MSE = 512.19$, $p < .001$, $\eta_p^2 = .27$, such that participants in the switched condition had lower performance on list four ($M = 61.0$, $SD = 35.3$) compared with list three ($M = 107.7$, $SD = 32.1$), $t(41) = 9.53$, $p < .001$, while performance was significantly higher for controls on list four ($M = 116.6$, $SD = 42.2$) than on list three ($M = 101.5$, $SD = 43.9$), $t(35) = 3.48$, $p = .001$. Importantly, both younger and older adults were unable to recover from the switch by the last list in regards to point totals. Specifically, younger adults' point totals were trending to be higher on list three ($M = 123.0$, $SD = 28.1$) than on list six ($M = 111.3$, $SD = 30.9$), $t(23) = 2.00$, $p = .058$, while older adults had reliably lower scores on list six than list three (list three: $M = 87.4$, $SD = 25.5$; list six: $M = 71.0$, $SD = 24.8$), $t(17) = 2.22$, $p < .05$.

Selectivity Index across Lists

In terms of selectivity indexes (see Figure 6), a 2 (Age: young, old) × 2 (Condition: switched, control) × 6 (List: 1, 2, 3, 4, 5, 6) mixed ANOVA found a main effect of age, $F(1, 74) = 18.71$, $MSE = 0.117$, $p < .001$,

FIGURE 6. Average selectivity index in each list for younger and older adults in Experiment 2. Error bars represent the standard error of the mean.



$\eta_p^2 = .20$ such that younger adults had higher overall selectivity indexes ($M = 0.74$, $SD = 0.14$) than older adults ($M = 0.61$, $SD = 0.14$). A main effect of condition, $F(1, 74) = 7.58$, $MSE = 0.117$, $p < .01$, $\eta_p^2 = .09$, was found such that switched participants had significantly lower selectivity ($M = 0.63$, $SD = 0.14$) compared to controls ($M = 0.72$, $SD = 0.14$). A main effect of list was found, $F(5, 370) = 11.43$, $MSE = 0.024$, $p < .001$, $\eta_p^2 = .13$, that parallels the other findings of this study—progressively higher selectivity scores across lists with the exception of list four $t(77) = 2.16$, $p < .05$. A condition by list interaction was found, $F(5, 370) = 6.70$, $MSE = 0.024$, $p < .001$, $\eta_p^2 = .08$, such that selectivity for switched participants on list three ($M = 0.74$, $SD = 0.15$) was greater than that on list four ($M = 0.56$, $SD = 0.26$) $t(41) = 4.76$, $p < .001$. However, selectivity for control participants on list three ($M = 0.69$, $SD = 0.22$) was less than that on list four ($M = 0.77$, $SD = 0.19$) $t(35) = 3.56$, $p = .001$. In order to measure the effects of the recovery from the switch in terms of selectivity, we compared index scores between younger and older adults in switched condition on lists three (i.e., immediately before the switch) and six (i.e., the last list of the experiment). Importantly, younger adults were able to match their performance on list three ($M = 0.76$, $SD = 0.12$) by list six ($M = 0.74$, $SD = 0.12$), $t(23) = 0.49$, $p = .63$, however older adults selectivity on list three ($M = 0.72$, $SD = 0.19$) was marginally higher than that on list six ($M = 0.63$, $SD = 0.22$), $t(17) = 1.55$, $p = .13$.

Probability of Recall as Function of Value

To determine whether participants were encoding and recalling higher value words across each list, we examined the proportion of words recalled from each quartile of values (–20 to –11, –10 to –1, 1–10, 11–20) from list three (immediately before the switch), list four (immediately after the switch), and list six (the last test—three lists after the switch) (see Table 1 for a summary). Again, three separate 2 (Age: young, old) × 2 (Condition: switched, control) × 4 (Quartile: first, second, third, fourth) mixed ANOVAs for the three lists were conducted. The ANOVA for list three found a main effects of age, $F(1, 74) = 61.21$, $MSE = 0.012$, $p < .001$, $\eta_p^2 = .45$, such that younger adults recalled a greater proportion of words across each quartile ($M = 0.28$, $SD = 0.06$) than older adults ($M = 0.18$, $SD = 0.05$). There was also a main effect of quartile, $F(3, 222) = 315.06$, $MSE = 0.017$, $p < .001$, $\eta_p^2 = .81$, such that the highest value items (i.e., the fourth quartile) were recalled the most often ($M = 0.55$, $SD = 0.15$) compared to the second highest quartile ($M = 0.35$, $SD = 0.19$), $t(77) = 6.88$, $p < .001$, as well as the other two quartiles. There was also an age by quartile interaction, $F(3, 222) = 21.15$, $MSE = 0.017$, $p < .001$, $\eta_p^2 = .22$, such that there was no significant difference in performance between the age groups for the first quartile (i.e., values –20 to –11), $t(76) = 1.40$, $p < .05$, but younger adults recalled a larger proportion of words from the fourth quartile than older adults, $t(76) = 5.66$, $p < .001$.

Because we were especially interested in performance immediately after the switch, we examined the effects of age, condition, and value on recall performance on list four. A main effect of age was found, $F(1, 74) = 35.77$, $MSE = 0.013$, $p < .001$, $\eta_p^2 = .33$, such that younger adults ($M = 0.24$, $SD = 0.06$) outperformed older adults ($M = 0.17$, $SD = 0.05$) on the average proportion of words recalled from the quartiles. A main effect of condition was found, $F(1, 74) = 54.48$, $MSE = 0.013$, $p < .001$, $\eta_p^2 = .42$, such that participants in the switched condition ($M = 0.16$, $SD = 0.06$) recalled fewer words across the quartiles compared to controls ($M = 0.25$, $SD = 0.05$). A main effect of quartile was also found, $F(3, 222) = 195.94$, $MSE = 0.020$, $p < .001$, $\eta_p^2 = .73$, such that words from the fourth quartile words were recalled the most often ($M = 0.50$, $SD = 0.19$) compared to the third quartile ($M = 0.27$, $SD = 0.17$), $t(77) = 6.94$, $p < .001$. A significant age by condition interaction was found, $F(1, 74) = 14.63$, $MSE = 0.013$, $p < .001$, $\eta_p^2 = .17$ such that, for the switched condition, the difference in performance between younger ($M = 0.17$, $SD = 0.05$) and older adults ($M = 0.14$, $SD = 0.05$) was trending towards significance, $t(40) = 1.78$, $p = .083$. In contrast, there was a large difference in performance between younger ($M = 0.32$, $SD = 0.07$) and older adults ($M = 0.19$, $SD = 0.05$) in the control condition, $t(34) = 6.01$, $p < .001$. An age by quartile interaction was found, $F(3, 222) = 17.24$, $MSE = 0.020$, $p < .001$, $\eta_p^2 = .19$ such that the difference in performance for the fourth quartile between younger ($M = 0.54$, $SD = 0.23$) and older adults ($M = 0.43$, $SD = 0.21$) was significant $t(76) = 2.27$, $p < .05$, $d = 0.52$, yet the difference in performance on the third quartile between younger ($M = 0.36$, $SD = 0.26$) and older adults ($M = 0.15$, $SD = 0.13$) was significantly larger $t(76) = 4.51$, $p < .001$, $d = 1.03$. The condition by quartile interaction was found, $F(3, 222) = 20.87$, $MSE = 0.020$, $p < .001$, $\eta_p^2 = .22$ such that fewer words were recalled by control ($M = 0.01$, $SD = 0.03$) than switched participants ($M = 0.04$, $SD = 0.07$) for the first quartile $t(76) = 2.68$, $p < .01$, but control participants ($M = 0.62$, $SD = 0.19$) recalled more words from the fourth quartile than switched participants ($M = 0.38$, $SD = 0.20$) $t(76) = 5.25$, $p < .001$. Lastly, the age by condition by quartile interaction was found for list four, $F(3, 222) = 3.31$, $MSE = 0.020$, $p < .05$, $\eta_p^2 = .04$. Specifically, when comparing the differences in performance of the third and fourth quartiles, older adults, compared to younger adults, were poorer at recalling the highest value information after receiving the switch.

The ANOVA for list six—the final list in the experiment that occurred three lists after the switch—yielded all three main effects and two interactions. Generally, the main effects paralleled the findings of the prior lists. Older adults ($M = 0.20$, $SD = 0.07$) were outperformed by younger adults ($M = 0.30$, $SD = 0.07$), $F(1, 74) = 30.38$, $MSE = 0.021$, $p < .001$, $\eta_p^2 = .29$, control participants ($M = 0.29$, $SD = 0.07$) outperformed switched participants ($M = 0.21$, $SD = 0.07$), $F(1, 74) = 27.91$, $MSE = 0.021$, $p < .001$, $\eta_p^2 = .27$, and the fourth quartile ($M = 0.59$, $SD = 0.19$) had the best performance overall, $F(3, 222) = 331.49$, $MSE = 0.018$, $p < .001$, $\eta_p^2 = .82$, while there was no difference between the first ($M = 0.02$, $SD = 0.04$) and second quartiles ($M = 0.01$, $SD = 0.04$), $t < 1$. There was a significant age by quartile interaction, $F(3, 222) = 13.96$, $MSE = 0.018$, $p < .001$, $\eta_p^2 = .16$, such that older adults ($M = 0.02$, $SD = 0.05$) recalled just as many words from the first quartile as younger adults ($M = 0.02$, $SD = 0.04$), yet recalled significantly fewer words ($M = 0.49$, $SD = 0.20$) from the fourth quartile than their younger counterparts ($M = 0.67$, $SD = 0.21$), $t(76) = 3.79$, $p < .001$. Similarly, a significant condition by quartile interaction was found, $F(3, 222) = 12.45$, $MSE = 0.018$, $p < .001$, $\eta_p^2 = .14$ such that there was no difference in recall between switched ($M = 0.02$, $SD = 0.04$) and control participants ($M = 0.02$, $SD = 0.05$) for the first quartile yet there was for the fourth ($M = 0.50$, $SD = 0.18$; $M = 0.68$, $SD = 0.22$, respectively), $t(76) = 3.95$, $p < .001$.

In summary, Experiment 2 replicated the main findings of Experiment 1, such that both age groups had difficulty overcoming high-value interference effects. However, in Experiment 2, when high-value words became negative values after the switch, older adults had a more pronounced deficit in performance, and could not recover to similar levels of performance relative to younger adults.

GENERAL DISCUSSION

The present study examined whether there are age-related differences in the costs of encoding information based upon value when these values are dynamic and change on later lists. Specifically, we were interested in age-related differences in the ability to update high-value information, and the detrimental effects of interference from previous high-value pairings. In two experiments, during the first three study-test cycles, younger adults outperformed older adults in terms of the number of words recalled and overall point totals, but performance was similar in terms of selectively remembering high-value words. However, when the values were switched after these three lists, both groups displayed substantial interference from the previous pairings. Although both groups improved with additional study-test cycles, only younger adults were able to fully recover from the interference effects in Experiment 1. In Experiment 2, where recall of words paired with negative point value would lower one's score and selectivity, a similar set of results were obtained, such that older adults displayed pronounced impairment in updating valuable information. These findings suggest that while both younger and older adults can remember information based on how valuable the information is, there are age-related differences in the ability to update value-directed remembering.

What could be a potential source of this differential impairment for younger and older adults? One candidate is that older adults were less able to inhibit prior low value words, consistent with previous research showing that older adults exhibit inhibitory deficits (e.g., Hasher & Zacks, 1988) and are especially prone to the detrimental effects of proactive interference (e.g., Jacoby, 1999). The present study shows that these detriments can occur in a value-based encoding task with the formerly high-value information creating proactive interference. Additionally, extra study-test practice can help both younger and older adults recover, although only to a certain degree for older adults. When values were changed (on List 4 in the present experiments), younger and older adults had to inhibit potent interfering material—the *least* valuable words, in order to retain the *most* valuable words possible. As shown in Table 1, value-directed remembering (i.e., progressively better recall performance for more valuable information), can be seen for both younger and older adults across both experiments in List 3, the list that occurred immediately before the switch. Performance immediately following the switch (List 4) showed relatively different findings—participants in the switched conditions exhibited detriments in performance for higher-value information (fourth quartile). Only the younger adults in Experiment 1 could match the performance of their matched controls. Older adults across both experiments, as well as younger adults in Experiment 2, could not match their control groups in terms of selectively recalling high-value information by the last list.

Although older adults demonstrated value-based switch costs, they do seem to progressively improve in performance across the subsequent lists after the switch (see all Figures), suggesting that older adults can overcome inhibitory deficits to a certain degree. Specifically, the difference between the proportion of high value words recalled between List 4 and List 6 was small in Experiment 1. However, prior research has shown that practice can help mediate older adults' performance under some conditions (e.g., Zacks & Hasher, 2006), and in the context of recovering from the effects of proactive interference (e.g., Jacoby et al., 2010). The present findings suggest mechanisms that guide value-based memory in both younger and older adults are influenced by value-based proactive interference, and this may be overcome through metacognitive awareness of limited memory capacity in older adults (e.g., Castel, 2008). Future research should explore what qualifies as the optimal amount of experience, or number of study-test cycles, that older adults would need to update valuable information. It would be also important to know how this ability might transfer to other materials, settings or tasks, and if this may be related to working memory capacity and metacognitive monitoring (e.g., Rhodes & Kelley, 2005), awareness of interference and forgetting (e.g., Friedman & Castel, 2011; Halamish, McGillivray, & Castel, 2011) or use of specific strategies that are related to metacognitive monitoring (e.g., Dunlosky & Hertzog, 2001). The present findings also provide some useful insight regarding how to prevent forgetting of important information, especially when the information was previously processed in terms of being irrelevant or less valuable (cf. Biss, Ngo, Hasher & Campbell, in press). Future research could examine how both younger and older adults can monitor the forgetting of both high and lower value information (see also Halamish et al., 2011), to determine if people are aware of how repetition and repeated testing can enhance memory for important information.

In both experiments, older adults did relatively well in terms of attending to value prior to the switch, but could not attend to high value information as well following the switch. Older adults may have been using a different strategy from younger adults—an effective strategy that has a cost of not being flexible—that resulted in recall of previously high-value items on later lists. For instance, while older adults were able to recall an equivalent number of high-value words relative to younger adults, they could not do so following the switch on List 4. This finding illustrates that older adults' ability to cope with proactive interference is dependent upon the nature of the competing material. In the two reported experiments, older adults likely had few words interfering with the encoding and retrieval of high value information. However, once values were switched on List 4 older adults struggled with the difficulty of prior high-value words competing with current high-value words. Even though the previously high-value words were, at the moment, less important to recall (or in the case of Experiment 2, important NOT to recall), they were likely interfering with the encoding and retrieval of current high-value words because they were once valuable, and due to age-related inhibitory deficits older adults had lower recall of the high-value words on the last three lists of the experiments. The implication for this explanation is that older adults' susceptibility to proactive interference and need for inhibitory control is dependent upon the nature of the would-be interfering material—when it is of the same relative value or importance as the to-be-remembered material memory performance will suffer, but not when the competing material is viewed as less important or valuable.

Younger adults may be more likely to update their strategy—using a less effective strategy that has the benefit of being more flexible—after the switch list, and can use the new item-value pairings to guide encoding operations. However, younger adults did not recover from the switch and attend to high values as well in Experiment 2 as they did in Experiment 1. This may indicate that younger adults are using an adaptive strategy that may not be as robust when they encounter negative value information, or that they are using a strategy similar to older adults, but can recover because they do not suffer as much from proactive interference. If this is the case, older adults may benefit from a directed forgetting instruction (e.g., Sahakyan, Delaney, & Goodmon, 2008) in the present task, to forget the previously studied information prior to the switch list, as this may reduce proactive interference. In light of memory impairments, older adults may use an adaptive metacognitive strategy of focusing on less information, but higher value items, in order to maximize scores, and it takes practice for this to evolve under interference.

In summary, this present study illustrates that both younger and older adults can benefit from task experience in the context of value-directed remembering, in terms of remembering important information, but there are costs associated with learning information in this fashion. While previous research has shown that both younger and older adults can use value to guide encoding operations, if established values are suddenly changed, it takes practice for the new-high value information to be updated and successfully recalled. In these conditions, both younger and older adults suffer from value-based proactive interference. This deficit is more pronounced in older adults and can prevent successful updating of important information, although successive study-test lists can lead to some improvements, a finding that sheds light on both age-related impairments in inhibition, and adaptive cognitive mechanisms that may be used in old age.

Original manuscript received 10 April 2012
Revised manuscript accepted 18 December 2012
First published online 30 January 2013

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